

09/351,199

CLAIM AMENDMENTS

1. (currently amended) A method for restoring a geometrically distorted copy of a reference image, said method comprising:

automatically determining a type and amount of distortion of said distorted copy; and

substantially reversing the distortion to form a reoriented image;

horizontally and vertically aligning the reoriented image with the reference image to form a realigned image; and

extracting a watermark from the realigned image.

2. (canceled)

3. (canceled)

4. (currently amended) A method ~~as recited in claim 1, for restoring a geometrically distorted copy of a reference image.~~ said method comprising:

automatically determining a type and amount of distortion of said distorted copy; and

substantially reversing the distortion to form a reoriented image;

wherein the step of automatically determining includes:

09/351,199

composing a geometric alteration of the distorted copy by making the distorted copy the same size as the reference image;

defining a safe area having safe pixels, wherein said safe area is an intersection of pixels in the reference image with pixels in the geometric alteration, and said safe pixels includes any pixel from the reference image or the geometric alteration which lies in the safe area;

selecting 'n' points in the safe area, wherein 'n' is at least three and not all 'n' points lie on a straight line;

building a list of 'n' reference centers, wherein each reference center corresponds to coordinates of a particular pixel lying closest to a particular one of said 'n' points;

constituting a plurality of pairs of sub-images, wherein each pair is centered at one of said reference centers and each pair is formed by a sub-image from the geometric alteration and a corresponding sub-image from the reference image;

minimally horizontally and vertically positioning from an original sub-image position to a new sub-image position any sub-image pair having any sub-image pixel lying outside the safe area, such that said any sub-image pixel lies within the safe area;

adjusting the reference center of said any sub-image pair to correspond to said new sub-image position;

computing a two-dimensional cross correlation surface from each of the 'n' pairs;

DOCKET NUMBER: YOR919990034US1

-4-

09/351,199

locating a horizontal,  $p_n$ , and a vertical,  $q_n$ , coordinate offset of the greatest peak on each cross-correlation surface;

calculating a plurality of distorted centers;

using the adjusted centers and the corresponding distorted centers to compute the coefficients matrix,  $A$ , of a pixel position interpolation equation; and

forming a sub-matrix,  $S_A$ , from the first, second, fourth and fifth elements of the matrix  $A$ .

5. (original) A method as recited in claim 4, further comprising:

computing a set of proposed reference centers based on the distorted reference centers and the pixel position interpolation equations;

computing the Euclidean distances between the proposed reference centers and the adjusted centers;

testing each Euclidean distances to determine if said each Euclidean distance is statistically improbable;

discarding said each distorted center and its corresponding adjusted center that define a Euclidean distance that is statistically improbable while retaining at least three not-discarded distorted centers and their corresponding adjusted centers; and

recomputing the coefficients matrix,  $A$ , of a pixel position interpolation equation using the at least three not-discarded distorted centers and corresponding adjusted centers.

09/351,199

6. (original) A method as recited in claim 4, wherein the steps of substantially reversing includes:

factoring the sub-matrix  $S_x$  into four primitive image manipulation matrices;

applying the four primitive image manipulation matrices to the geometric alteration to produce a reoriented image;

making the geometric alteration identical to the reoriented image if any primitive image manipulation matrix produces a distortion greater than a predetermined threshold, said distortion determined by examining all iteration-to-iteration incremental changes in the Euclidean distances; and

repeating all the steps of claim 4 except the step of composing, all the steps of claim 5, and the steps of factoring, applying and making until no primitive image manipulation matrix produces a distortion greater than the predetermined threshold.

7. (original) A method, as recited in claim 4, wherein the step of horizontally and vertically aligning includes translating horizontally the reoriented image by the value of the third coefficient of the matrix,  $A$ , and translating vertically the reoriented image by the value of the sixth coefficient of the matrix,  $A$ , to form the realigned image.

8. (currently amended) A method as recited in claim 1 3, wherein the step of composing includes:

shrinking or enlarging the distorted copy vertically by pixel interpolation or extrapolation such that the produced geometric alteration has a same height as the reference image, and

09/351,199

shrinking or enlarging the produced geometric alteration horizontally by pixel interpolation or extrapolation to have the same width as the reference image.

9. (original) A method as recited in claim 4, wherein the coordinate offsets are non-integers and the step of locating includes using interpolation.

10. (original) A method, as recited in claim 1, wherein the reference image is an original unmarked image.

11. (original) A method as recited in claim 4, wherein the step of computing includes:

comparing a region in the geometric alteration surrounding each of said reference centers with regions in the reference image shifted in position by a multiplicity of coordinate offsets;

ascertaining horizontal and vertical coordinate offsets of each selected reference center as being the horizontal and vertical offset at which the region in the geometric alteration and the region on the reference image most nearly match; and

calculating the distorted centers from the coordinate offsets and the corresponding reference centers.

12. (original) A method as recited in claim 11, wherein the step of comparing includes:

using a modified cross correlation function in which the Fourier transform of the cross correlation function is computed, wherein magnitudes of the Fourier transform coefficients are modified to make said magnitudes uniform, and

DOCKET NUMBER: YOR919990034US

-7-

09/351,199

using an inverse Fourier transform to compute the modified correlation function.

13. (original) A method as recited in claim 11, wherein the step of comparing includes:

using a weighted cross correlation function in which the Fourier transform of the cross correlation function is computed, wherein a weighted sum of the ordinary and modified Fourier transform coefficients is formed, and

using an inverse Fourier transform to compute the weighted correlation function.

14. (original) A method as recited in claim 8, wherein the step of ascertaining includes:

composing a geometric alteration of the distorted copy by making the distorted copy the same size as the reference image;

defining a safe area having safe pixels, wherein said safe area is an intersection of pixels in the reference image with pixels in the geometric alteration, and said safe pixels includes any pixel from the reference image or the geometric alteration which lies in the safe area;

building a list of reference centers, wherein each reference center corresponds to coordinates of a particular pixel in the safe area lying closest to a particular one of said at least three pixel locations;

computing a plurality of corresponding distorted centers;

using the reference centers and the corresponding distorted centers to compute coefficients of a matrix, A, of pixel position interpolation equations;

DOCKET NUMBER: YOR919990034US1

-8-

09/351,199

testing each distorted center to determine if said each distorted center is statistically improbable; and

discarding each distorted center that is statistically improbable while retaining at least three not-discarded distorted centers, until no more distorted centers are discarded.

15. (currently amended) An article of manufacture comprising a computer usable medium having computer readable program code means embodied therein for causing a restoring of a geometrically

distorted copy of a reference image, the computer readable program code means in said article of manufacture comprising computer readable program code means for causing a computer to effect:

automatically determining a type and amount of distortion of said distorted copy; and

substantially reversing the distortion to form a reoriented image;

aligning the reoriented image with the reference image to form a realigned image; and

extracting a watermark from the realigned image.

16. (canceled)

17. (canceled)

18. (original) An article of manufacture as recited in claim 15, wherein the reference image is a copy of an original unmarked image.

DOCKET NUMBER: YOR919990034US1

-9-

09/351,199

19. (original) An article of manufacture as recited in claim 15, wherein the step of automatically determining includes:

selecting a set of at least three reference centers in the geometric alteration;

comparing a region in the geometric alteration surrounding each of said reference centers, with regions in the reference image shifted in position by a multiplicity of coordinate offsets;

ascertaining horizontal and vertical coordinate offsets of each selected reference centers as being the horizontal and vertical offset at which the region in the geometric alteration and the region on the reference image most nearly match; and

determining the type and amount of distortion from the coordinate offsets and the set of reference centers.

20. (original) An article of manufacture as recited in claim 19, wherein the step of comparing includes:

using a modified correlation function in which the Fourier transform of the correlation function is computed, wherein the magnitudes of the Fourier transform coefficients are modified to make said magnitudes uniform, and

using an inverse Fourier transform to compute the modified correlation function.

21. (original) An article of manufacture as recited in claim 19, wherein the step of ascertaining includes performing a least-squares fit on the horizontal and vertical coordinate offsets of the set of reference centers.

DOCKET NUMBER: YOR919990034US1

-10-



09/351,199

22. (currently amended) A computer program product comprising a computer usable medium having computer readable program code means embodied therein for causing a readjusting of a geometrically distorted copy of a reference image, the computer readable program code means in said computer program product comprising computer readable program code means for causing a computer to effect:

automatically determining a type and amount of distortion of said distorted copy; and

substantially reversing the distortion to form a reoriented image;

horizontally and vertically aligning the reoriented image with the reference image to form a realigned image; and

extracting a watermark from the realigned image.

23. (currently amended) An apparatus for restoring a geometrically distorted copy of a reference image, said method comprising:

means for automatically determining a type and amount of distortion of said distorted copy; and

means for substantially reversing the distortion to form a reoriented image;

means for horizontally and vertically aligning the reoriented image with the reference image to form a realigned image, and

means for extracting a watermark from the realigned image.

24. (canceled)

DOCKET NUMBER: YOR919990034US1

-11-

09/351,199

25. (canceled)

26. (original) An apparatus as recited in claim 23, wherein the means for automatically determining includes:

means for composing a geometric alteration of the distorted copy by making the distorted copy the same size as the reference image;

means for defining a safe area having safe pixels, wherein said safe area is an intersection of pixels in the reference image with pixels in the geometric alteration, and said safe pixels includes any pixel from the reference image or the geometric alteration which lies in the safe area;

means for selecting 'n' points in the safe area, wherein 'n' is at least three and not all 'n' points lie on a straight line;

means for building a list of 'n' reference centers, wherein each reference center corresponds to coordinates of a particular pixel lying closest to a particular one of said 'n' points;

means for constituting a plurality of pairs of sub-images, wherein each pair is centered at one of said reference centers and each pair is formed by a sub-image from the geometric alteration and a corresponding sub-image from the reference image;

means for minimally horizontally and vertically positioning from an original sub-image position to a new sub-image position any sub-image pair having any sub-image pixel lying outside the safe area, such that said any sub-image pixel lies within the safe area;

DOCKET NUMBER: YOR919990034US1

-12-

09/351,199

means for adjusting the reference center of said any sub-image pair to correspond to said new sub-image position;

means for computing a two-dimensional cross correlation surface from each of the 'n' pairs;

means for locating a horizontal,  $p_n$ , and a vertical,  $q_n$ , coordinate offset of the greatest peak on each cross-correlation surface;

means for calculating a plurality of distorted centers;

means for using the adjusted centers and the corresponding distorted centers to compute the coefficients matrix, A, of a pixel position interpolation equation; and

means for forming a sub-matrix,  $S_A$ , from the first, second, fourth and fifth elements of the matrix A.

27. (original) An apparatus as recited in claim 26, further comprising:

means for computing a set of proposed reference centers based on the distorted reference centers and the pixel position interpolation equations;

means for computing the Euclidean distances between the proposed reference centers and the adjusted centers;

means for testing each Euclidean distances to determine if said each Euclidean distance is statistically improbable;

means for discarding said each distorted center and its corresponding adjusted center that define a Euclidean distance that is statistically improbable while retaining at least three

09/351,199

not-discarded distorted centers and their corresponding adjusted centers; and

means for recomputing the coefficients matrix, A, of a pixel position interpolation equation using the at least three not-discarded distorted centers and corresponding adjusted centers.

28. (original) An apparatus as recited in claim 26, wherein the coordinate offsets are non-integers, and the means for locating includes using interpolation.

29. (original) A method as recited in claim 1, wherein the steps of automatically determining and substantially reversing are repeatedly applied until an amount of the distortion falls below a given threshold.

30. (original) A method as recited in claim 29, wherein the given threshold is less than a 0.5 pixel spacing.

31. (currently amended) A method comprising:

automatically measuring the degree of distortion imparted upon a distorted replica of an original image;

substantially reversing the degree of distortion of the distorted replica to form an undistorted image; and

aligning the undistorted image with the original image; and

extracting a watermark from the realigned image.

09/351,199

32.. (original) A method as recited in claim 31, further comprising determining whether the distorted replica image has been geometrically distorted relative to another form of the original image.

33. (currently amended) An article of manufacture comprising a computer usable medium having computer readable program code means embodied therein for causing ~~restoration of watermark extraction from an image~~, the computer readable program code means in said article of manufacture comprising computer readable program code means for causing a computer to effect:

automatically measuring the degree of distortion imparted upon a distorted replica of an original image;

substantially reversing the degree of distortion of the distorted replica to form an undistorted image; and

aligning the undistorted image with the original image; and

extracting a watermark from the realigned image.

34. (currently amended) An article of manufacture as recited in claim ~~33~~ 32, the computer readable program code means in said article of manufacture further comprising computer readable program code means for causing a computer to effect determining whether the distorted replica image has been geometrically distorted relative to another form of the original image.

35. (original) A method as recited in claim 4, wherein the step of selecting 'n' points includes employing a simulated mesh with knots.